Heavy Ions from the SPS to the LHC*

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In February, representatives from some of the seven collaborations gathering data on Pb+Pb interactions at the CERN SPS summarized the results of the heavy ion program. They presented "compelling evidence that a new state of matter has been created". This new state of matter is expected to be the quark-gluon plasma (QGP). The ancient alchemists attempted to turn lead into gold. At the CERN SPS, the much coveted golden nugget of QGP has proved almost as elusive as the alchemists' dream. That is because the QGP itself cannot be directly observed with the detectors, only the end result—a spray of produced particles. As the plasma expands and cools, the deconfined quarks and gluons must regroup into colorless hadrons. One hopes to learn about the initial, golden, plasma by studying the final shades of gray in the aftermath.

Some of the evidence cited from the lead beam data includes an apparent expansion of the matter in the transverse direction, an enhanced production of strange hadrons, particularly hadrons with more than one strange quark, and a suppression of $J/\psi(c\overline{c})$ production. All this data, taken together, provide evidence that something interesting is happening in nucleus-nucleus collisions, certainly much more than random collisions of independent nucleons.

Because of the indirect nature of the evidence, there is no clear concensus among the heavy ion community that the plasma has been definitely produced and not all conventional explanations can be ruled out. The lifetime of the plasma, if it has been produced, is very short, on the order of a few fermi/c, and no direct observables from the initial state have been clearly seen. Therefore, it is necessary to go to higher energies where the plasma will be longer lived and more signals from the early stage may appear.

Two machines are planned that will attain more energy in heavy ion experiments by running in collider mode rather than the fixed target style at the CERN SPS, RHIC and the LHC. While RHIC is a dedicated heavy ion collider which should be able to identify the plasma and study some of its properties, the higher energy of the LHC will be an advantage for certain signals from the early state.

The J/ψ suppression studied at the SPS will be more difficult to track directly at the LHC due to the large expected suppression at the much higher energy and significant contributions to J/ψ production by B meson decays. Instead, the $\Upsilon(b\overline{b})$ resonances will provide more direct indications of QGP effects. Direct suppression of the Υ itself is predicted to be possible only at the LHC, making it especially interesting. Conventional interactions of the Υ are reduced compared to those of the J/ψ because of its smaller radius. The rate is large enough to make it experimentally feasible to study Υ suppression at the LHC. Systematic errors can be reduced by studying ratios such as Υ'/Υ as a function of transverse momentum. CMS can measure the Υ, Υ' and Υ'' resonances well.

Energy loss of fast partons moving through matter is predicted to occur in normal hadronic matter through rescattering processes but the effect is likely to be much stronger in a QGP. Truly high transverse momentum processes such as high E_T jet pairs and single jets in combination with a high E_T photon or Z^0 may be used to probe energy loss effects. The single jet rate relative to the dijet rate may be enhanced because one jet may lose enough energy that its jet-like properties may be unobservable. The energy loss rate could be determined from the E_T distribution of the photon or Z^0 opposite a jet. The CMS detector is well suited for measuring high E_T jets.

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